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NBSIR 73-170

Fire Endurance Test of an Interdwelling Double Wall Constructed of Polyurethane Foam-Filled Sandwich Panels

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Center for Building Technology
Institute for Applied Technology
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Final Report

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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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ABSTRACT

As a part of the evaluation of housing systems of Operation BREAKTHROUGH, a standard ASTM E 119 fire endurance test was performed on a double wall assembly comprising a loadbearing interdwelling (party) wall for single family attached housing.

The test was generally in accordance with the requirements of ASTM E 119, Fire Tests of Building Construction and Materials. The applied live load was 678 pounds per linear foot (plf) per wall and the test results are valid only for walls of similar construction loaded at or below the stress level developed by this loading.

The fire endurance of the first (fire-exposed) wall, based on structural load failure, was 1 hr. and 4 min. The test was discontinued at 1 hr. 06 min. because of untenable conditions in the test building resulting from smoke and combustion gases released by the polyurethane foam insulation in the wall.

Key Words: Fire endurance; fire test; housing systems; interdwelling wall; load failure; modular construction; Operation BREAKTHROUGH; polyurethane foam; toxic gases

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1. INTRODUCTION

A standard fire endurance test was conducted to measure the fire endurance of a loadbearing interdwelling double wall assembly. The test was performed at the Fire Test Laboratories of the National Bureau of Standards, Washington, D.C., on January 20, 1972. It was part of the evaluation of housing systems under Operation BREAKTHROUGH sponsored by the Department of Housing and Urban Development.

The double wall, which is required to be a fire barrier between two adjacent living units, was made up of two identical sandwich panels erected parallel to each other. Each panel consisted of two layers of gypsum board over a layer of plywood, a polyurethane foam insulation core, and a layer of cement asbestos board. The gypsum board formed the interior (room) side of each unit, while the cement asbestos board formed the opposite or what would normally be the exterior side of a unit. The construction was innovative to the extent that available data from existing fire tests were not applicable. Although the fire performance of conventional walls composed of gypsum board and plywood sheets has been long established, the characteristics of an assembly of panels with plastic foam cores and the behavior of the aluminum extrusion joints under severe fire conditions required investigation. The construction and assembly of this test specimen was representative of actual construction used in the field.

The fire exposure followed the requirements of Standard Methods of Fire Tests of Building Constructions and Materials ASTM E 119[1/] for loadbearing walls.

2. CONSTRUCTION

The assembly consisted of two identical 8 foot high by 16 foot long walls parallel to each other and separated by a two inch air space. Each wall consisted of 1/8 inch cement asbestos board as an exterior surface and 5/16 inch C-D interior grade plywood covered with two layers of 1/2 inch type X gypsum board as a interior (room) side finish. The three inch space between the exterior and interior surface had been filled with foamed-in-place rigid polyurethane insulation to provide thermal insulation.

Each wall was received as an assembly made up of four-4 foot wide by 8 foot high panels. The panel joint consisted of an aluminum spline engaging the channels of the aluminum extrusion surround on the edges of each panel. Epelene propylene--dyene monomer (EPDM) resilient wedges (filler strip), which ran the full height of the panel, had been driven in each side of the joint. The top and bottom edges of the panel were closed with the same extruded aluminum surround which was used on the sides of the panels. The plywood and asbestos boards were force fit within channels of the aluminum extrusion shape. The details of the construction are shown in Figures 1, 2 and 3.

[1/] Standard Methods of Fire Tests of Building Construction and Materials, American Society for Testing and Materials Designation E 119-71, available at 1916 Race St., Philadelphia, Pa. 19103

The two walls were mounted in the furnace frames separated by a 2 inch air space. Two layers of 1/2 inch type X gypsum board were fastened to the plywood face of the walls using type S, bugle head screws spaced as shown in Figure 4. The panel joints and gypsum board joints were staggered. Each complete wall assembly weighed 57 pounds per linear foot and its thickness was 4-7/16 in.

Since the 8 foot height of the specimen was less than 10 foot high opening of the test frame, a filler piece was placed at the top of the specimen. The filler piece was made up of 2 x 12 (nominal) pine wood, protected on the fire side with two layers of 5/8 inch Type X gypsum board and sprayed fire protective vermiculite plaster on metal lath, and on the unexposed side, with a single layer of 5/8 inch Type X gypsum board. The filler piece was expected to have sufficient fire endurance and rigidity during the test so as not to affect the test results.

3. INSTRUMENTATION

The instrumentation consisted of thermocouples, deflection measuring devices and loading equipment. A total of 52 Chromel-Alumel (type K) thermocouples were installed as follows: 40 thermocouples internally in the panels and air space, and 12 surface thermocouples on the unexposed surface of the second wall panel. The surface thermocouples were placed under standard 6 inch by 6 inch by 0.4 inch felted asbestos pads. Figure 5 shows the locations of the thermocouples. Thermocouples between foam insulation and plywood, and between foam insulation and asbestos boards, were installed by the panel manufacturer during plant assembly. The remainder were installed by NBS personnel.

The temperatures measured by the thermocouples were printed out at 2 minute intervals on a data logger from which they were punched onto cards for processing and plotting by computer. The lateral deflection indicator consisted of a wire which was stretched horizontally in front of the specimen at mid-height. At the start of the test the wire was 3-1/4 inches from the unexposed surface; the distance from the wire to the wall surface was measured periodically during the test by a ruled measuring device.

The vertical movement of each wall during the test was measured by four mechanical extensometers which were placed at the mid-points under the bottom of each wall. The photograph in Figure 6 shows the unexposed surface of the specimen, the connections of the thermocouples, the loading jacks and the mechanical extensometers.

4. DESCRIPTION OF TEST

4.1 Loading

Five minutes prior to the start of the test, a load of 735 plf (678 plf live load + 57 plf dead load) was applied to each wall independently though four hydraulic jacks at the bottom of the specimen. The total applied load per wall was 11,760 lb.

The applied load of 678 plf corresponded to representative loading for the intended residential occupancy and was not necessarily the load required to develop the working stresses in the assembly.

4.2 Furnace Conditions

The average temperature inside the furnace was measured by 12 Type K thermocouples enclosed in sealed 1/2 inch diameter wrought iron pipe which were equally distributed inside the furnace. The ends of the thermocouples were placed six inches from the exposed face of the specimen. The average furnace temperature was regulated to follow the standard ASTM E 119 temperature-time curve by manual control of the gas flow to the burners. The actual furnace time temperature curve is shown in Figure 7.

The pressure measurement within the furnace was made with a dish shaped probe connected to a pressure difference meter with tubing. The pressure probe consisted of 1/8 inch inside diameter stainless steel tubing attached to the edge of a 1-1/8 inch diameter flat metal disk connected to a small hole in the center of the disk. The disk was positioned normal to the upward flow of gas. The test was run with the furnace neutral pressure point located at one-third height of the specimen above the bottom of the specimen.

4.3 Fire Performance Criteria

The fire endurance of a wall according to ASTM E 119 is the time required to reach the first occurrence of the following criteria of failure:

1. Inability to sustain the applied load.
2. Passage of flame or gas through the structure to the unexposed surface hot enough to ignite cotton waste.
3. A temperature rise of 250°F (139°C) average of all the thermocouples, or 325°F (181°C) maximum at any one point above the initial temperature on the unexposed surface.

5. TEST RESULTS

The average and the maximum temperature rises on the unexposed surface during the test are shown in Figure 8. The average and maximum temperature rise across the assembly are shown in Figures 9 and 10. It is clear that very little heat was transmitted through the double wall assembly during the 66 min. test.

Structural failure of the first (fire-exposed) wall occurred at 64 minutes, as evidenced by a sudden rapid deflection and inability to maintain the applied hydraulic load. Immediately prior to the failure of the first wall, its measured vertical deflection was 3/4 inch.

The second wall did not fail during the test. Lateral and vertical deflections on the second wall were barely perceptible during the test. The test results were inconclusive with respect to the fire endurance of the double wall assembly, since the test was terminated prematurely because the smoke generated by the test assembly made conditions untenable for the personnel involved. Most of the smoke was coming out between the bottom edges of the assembly and furnace frame. See "Test Observations."

Figure 11 shows the fire side of the wall assembly immediately after removal from the furnace. Note buckling (and melting) of the aluminum frame in the first wall. The buckling of the vertical aluminum frame occurred at the time of load failure of the first wall. The flaming at the joint is from the resilient wedge behind the joint. The asbestos boards of the first fire side wall were also buckled and cracked but no large holes were observed.

6. DISCUSSION

The construction of the specimen was symmetrical, so that the same fire resistance would have been expected if the opposite side of the assembly had been exposed to fire.

Based on results of several different loaded double wall tests performed under Operation BREAKTHROUGH, the second (unexposed) wall of a double wall assembly may provide, on the average, an additional 75 percent fire endurance time relative to the first (fire-exposed) wall. This relation may apply when the construction of each wall in the double wall configuration is similar, when the wall surfaces that face the internal air space are not combustible, and when failure or collapse of the fire-exposed wall does not structurally damage the second wall.

In accordance with the above, the fire endurance of the double wall assembly may be estimated as 1 hr:52 min (64 x 1.75 = 112).

A load of 678 plf was applied to each wall and the result of this test is applicable only to similar wall structures loaded to develop stresses not exceeding those developed in this structure.

TABLE I

Log of Test Observations

Time min:sec	Observations
0:00	Start of test
1:30	Paper on exposed gypsum board burning.
4:00	All the paper on the exposed gypsum board consumed.
11:00	The spackling on exposed vertical joints peeling off.
12:00	There appears to be an opening in the south end horizontal joint.
14:00	There is blackening at top of specimen (exposed side south end). Flaming at the intersection of horizontal and south vertical joint. (See Figure 12.)
17:00	There are cracks and flaming at the center of the horizontal joint.
19:00	There is increased flaming at the south end joint probably the paper on the second layer of gypsum board is burning. Quite a bit of steam being emitted at the center bottom on the room side.
20:00	There is flaming at the horizontal joints both north and south. Burning smell noticed.
27:00	Very little burning at north center horizontal joint, but considerable burning at south end of horizontal joint.
28:00	At the south end there is a crack at the top of the specimen. Quite a bit of flaming whole length of the vertical joint. Some localized buckling on the fire side at mid-center.
43:00	Possible opening at top of upper south side (exposed side).
49:00	Joints on fire side have opened up 1/2 inch. Smoke coming out at the edges of the assembly.

Time	Observations
min:sec	
50:00	Increased flaming at north horizontal and center lower (vertical) joints. (Apparently plywood is burning.)
51:00	Rapid rate of flaming at south upper section and halfway across north (upper) section and halfway down south section vertically.
53:00	Dark brown irritating smoke coming out lower south* and center portions of the assembly on room side.
58:00	One inch openings in the north end horizontal joint (exposed side).
59:00	Thick brown smoke from specimen filling room. Mostly smoke coming out between bottom edges of the assembly and and furnace frame. Black smoke and flames are coming out of stack. Visibility in building is very poor.
61:00	First wall on furnace side buckling inward at south horizontal and lower center vertical joints. (See Figure 13).
62:00	There is a great amount of smoke filling the whole room. The first wall falling inward.
64:00	Black smoke both inside and outside the furnace. Unable to maintain load. Load failure of the first wall.
66:00	END OF TEST - Untenable smoke conditions in building.
68:00	Black smoke and some flame coming out of furnace stack.

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* For identifying the location of an occurrence, the two ends of the assembly were differentiated according to this orientation.

Appendix I

SI Conversion Units

In view of present accepted practice in this country in this technological area, common US units of measurement have been used throughout this paper. In recognition of the position of the United States as a signatory to the General Conference on Weights and Measurements which gave official status to the metric SI system of units in 1960, we assist readers interested in making use of the coherent system of SI units by giving conversion factors applicable to US units used in this paper.

Length

1 in = 0.0254 meter
1 ft = 0.3048 meter

Mass

1 lb = 0.45 Kilograms

Stress

1 psf = 47.88 newton/meter^2
1 psi = 0.332 newton/meter^2
1 plf = 13.49 newton/meter

Temperature

Temperature in °F = 9/5 (temperature in °C) + 32°F

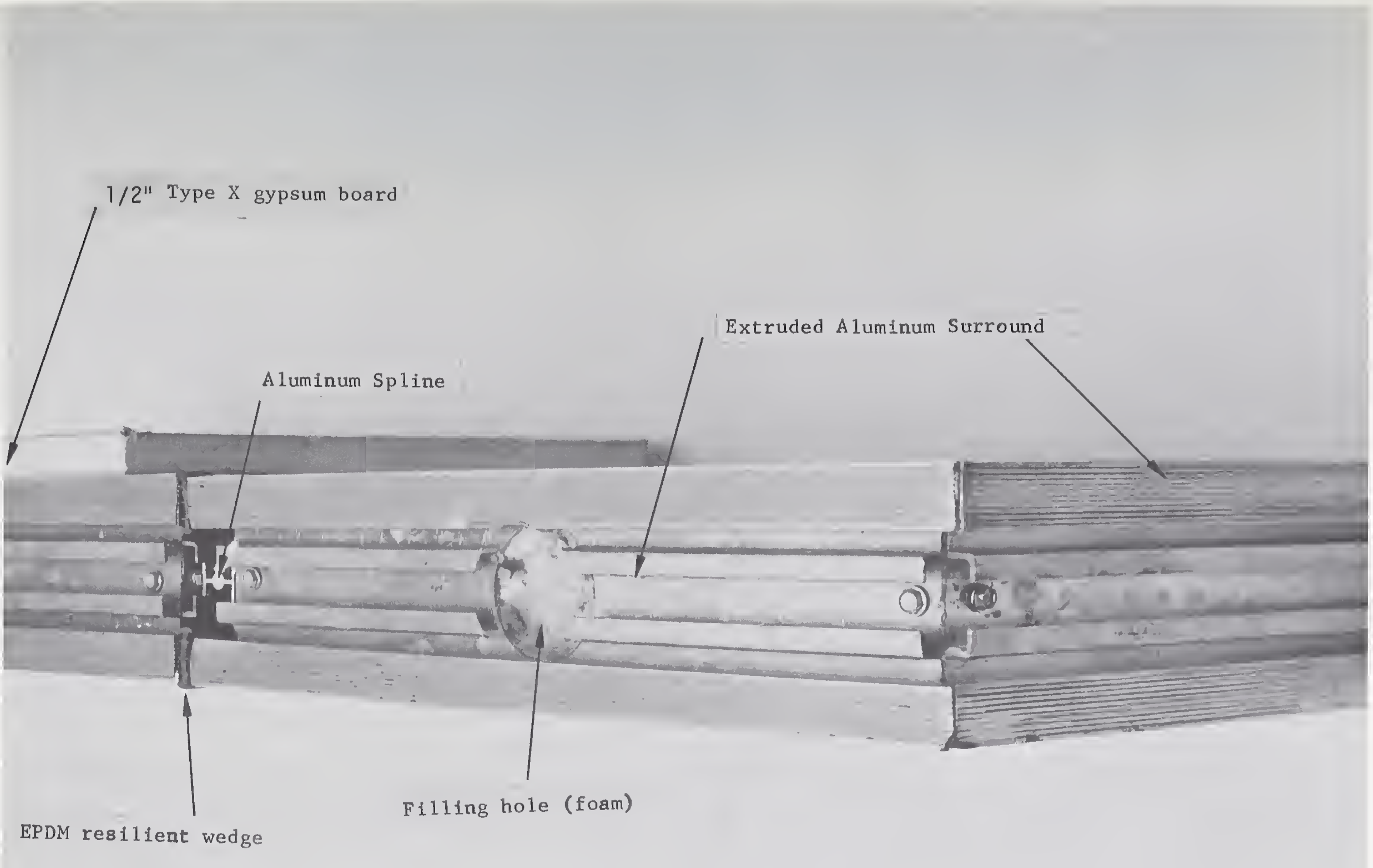


Figure 1 Construction Details

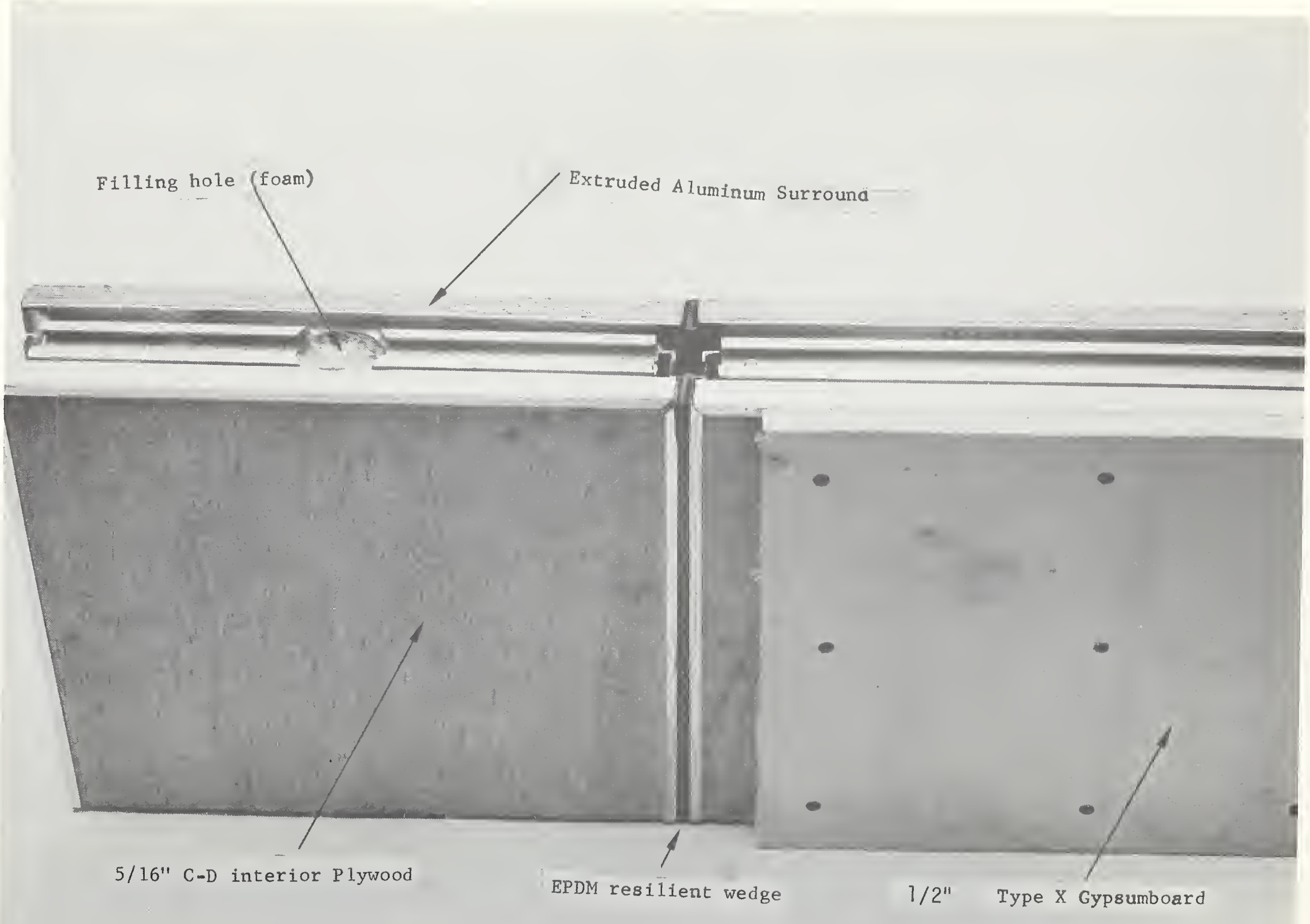


Figure 2 Construction Details

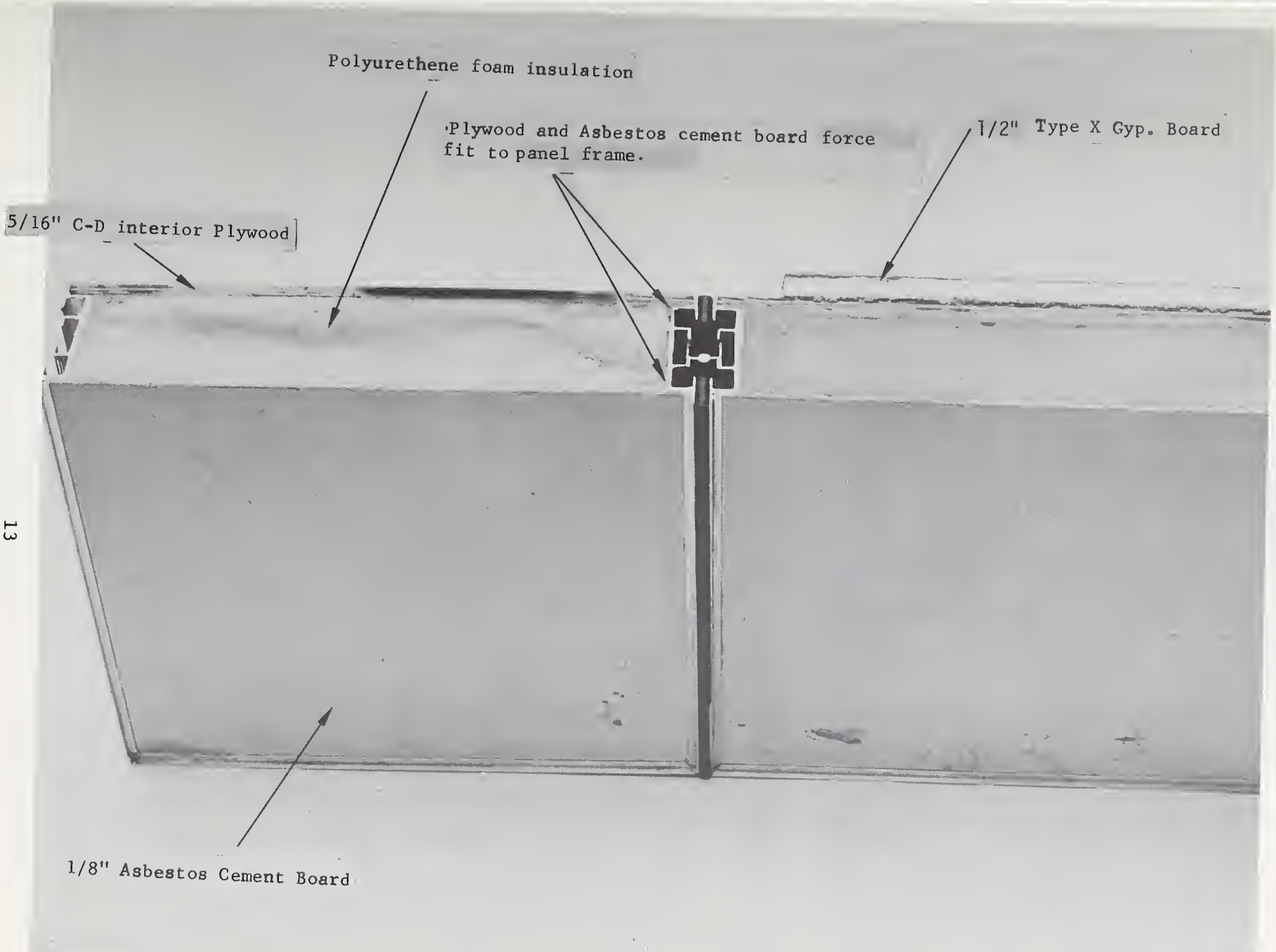
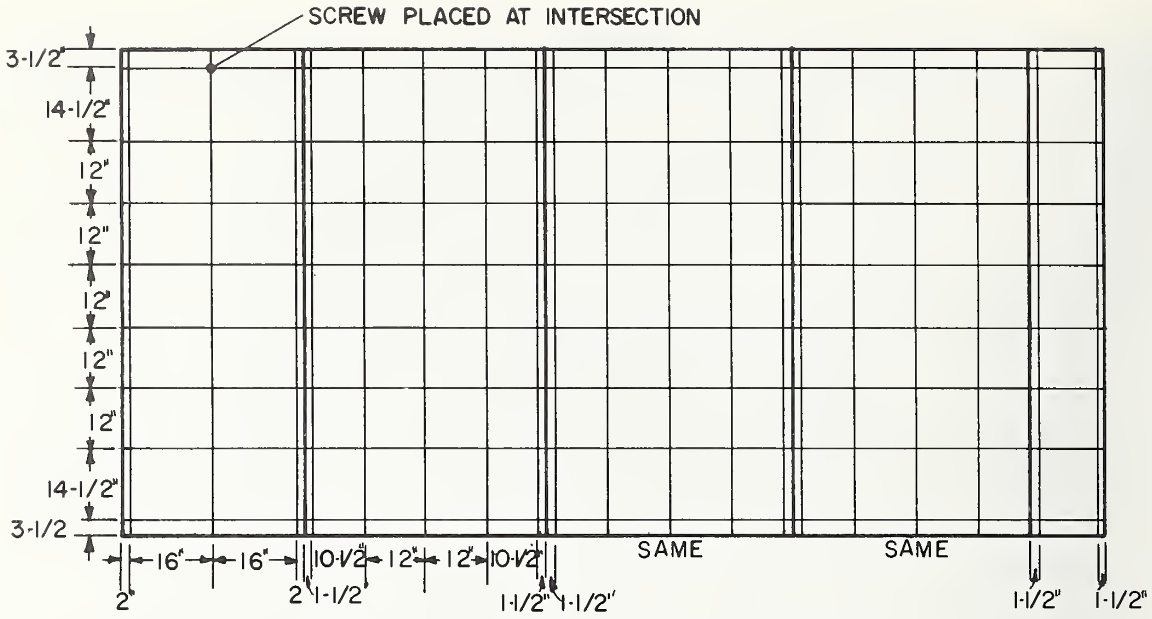
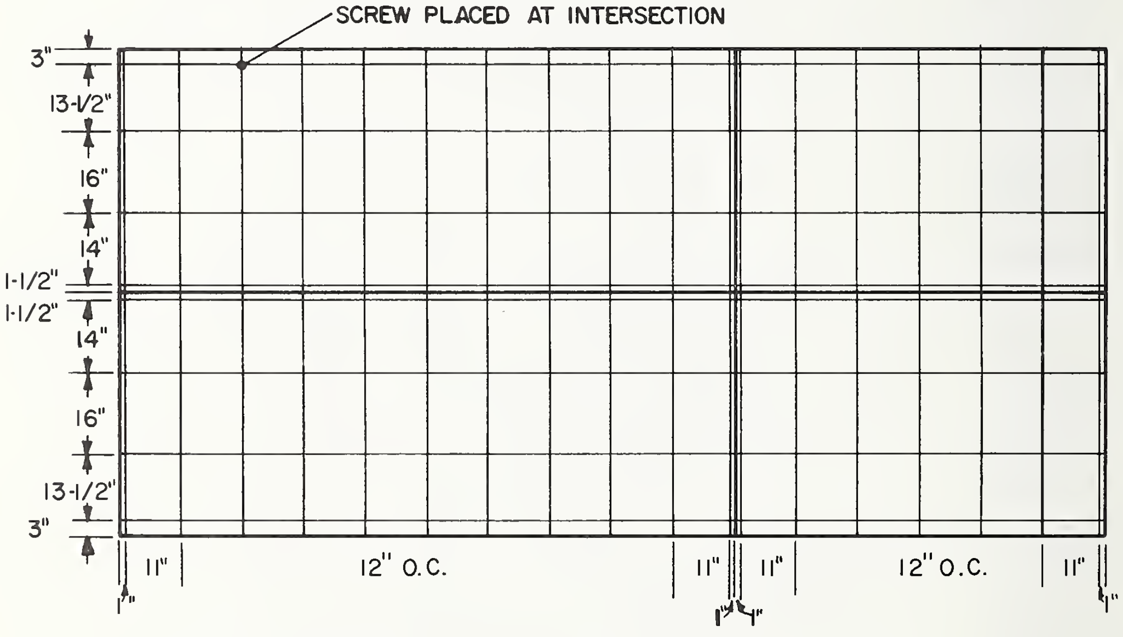

Polyurethene foam insulation
'Plywood and Asbestos cement board force fit to panel frame.
1/2" Type X Gyp. Board
5/16" C-D interior Plywood
1/8" Asbestos Cement Board

Figure 3 Construction Details



FASTENER SCHEDULE FOR 1st LAYER OF 1/2 in TYPE X



FASTENER SCHEDULE FOR 2nd LAYER OF 1/2 in TYPE X

Figure 4. Fastener schedules for 1st and 2nd layers of gypsum board on each wall.

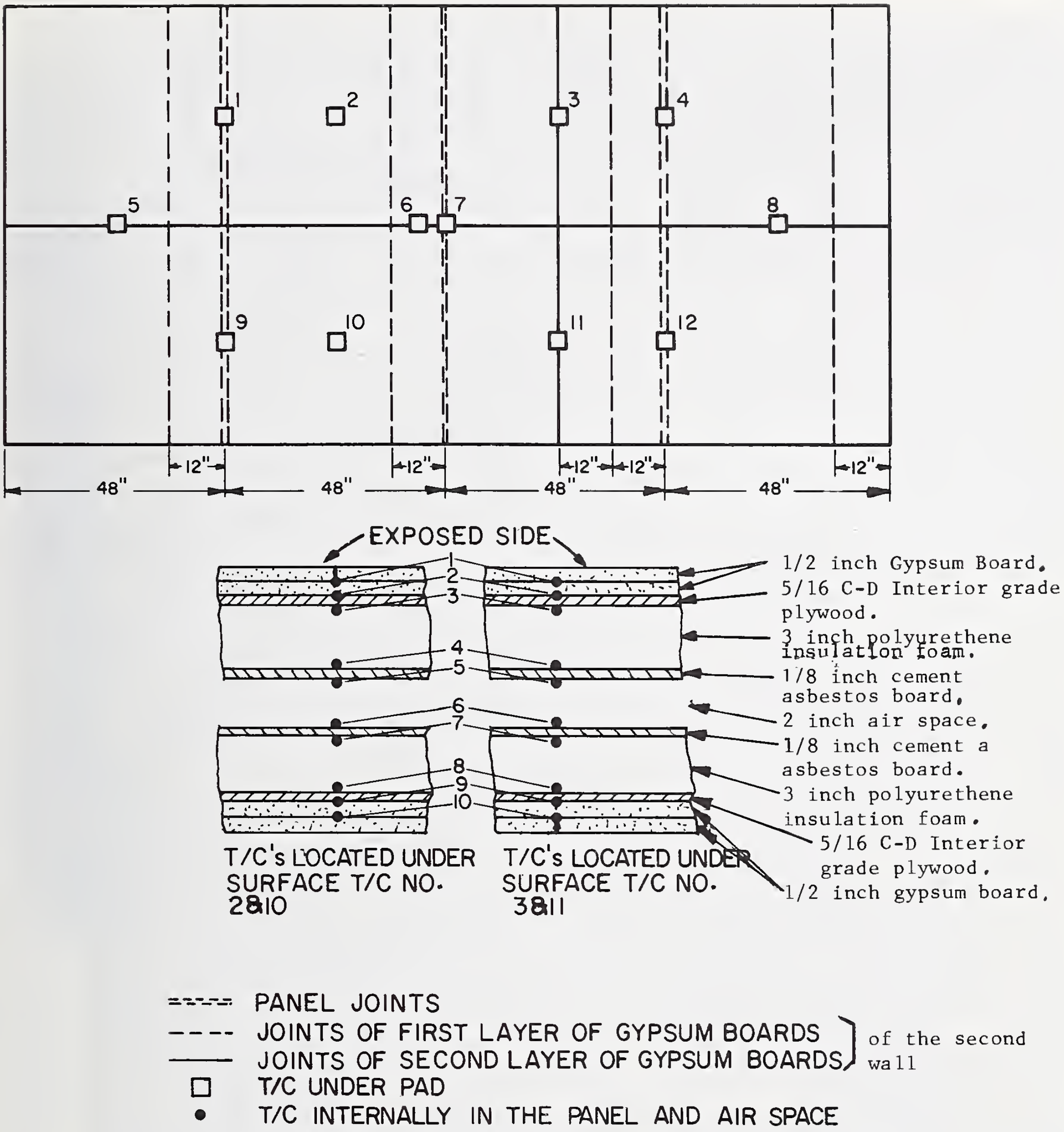

1
2
3
4
5
6
7
8
9
10
11
12
12"
12"
12"
12"
12"
48"
48"
48"
48"
EXPOSED SIDE
1
2
3
4
5
6
7
8
9
10
1/2 inch Gypsum Board.
5/16 C-D Interior grade plywood.
3 inch polyurethene insulation foam.
1/8 inch cement asbestos board.
2 inch air space.
1/8 inch cement a asbestos board.
3 inch polyurethene insulation foam.
5/16 C-D Interior grade plywood.
1/2 inch gypsum board.
T/C's LOCATED UNDER SURFACE T/C NO. 2&10
T/C's LOCATED UNDER SURFACE T/C NO. 3&11
PANEL JOINTS
JOINTS OF FIRST LAYER OF GYPSUM BOARDS
JOINTS OF SECOND LAYER OF GYPSUM BOARDS
of the second wall
T/C UNDER PAD
T/C INTERNALLY IN THE PANEL AND AIR SPACE

Figure 5. The locations of the interior and surface thermocouples.

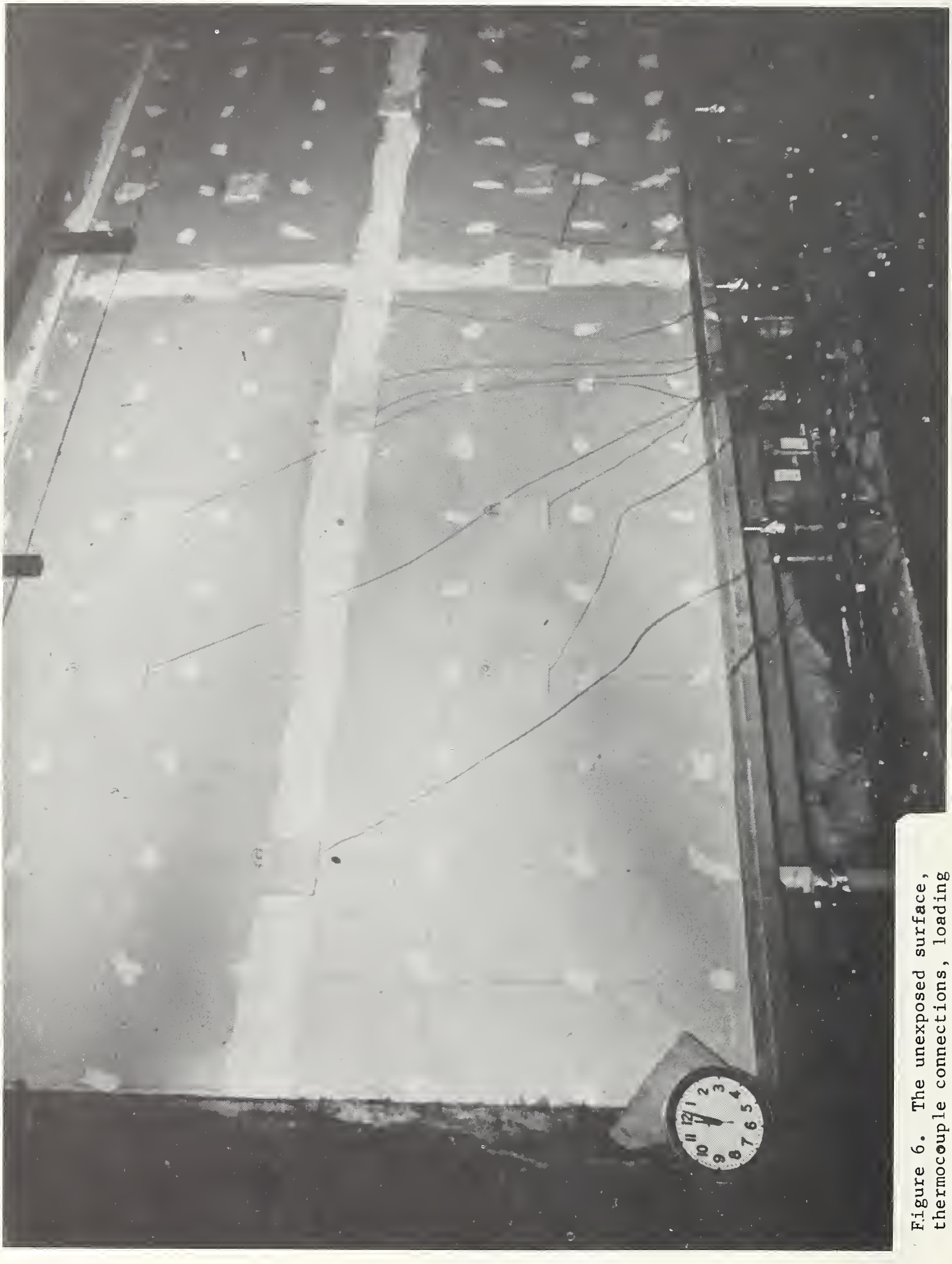


Figure 6. The unexposed surface, thermocouple connections, loading jacks, mechanical extensometers.

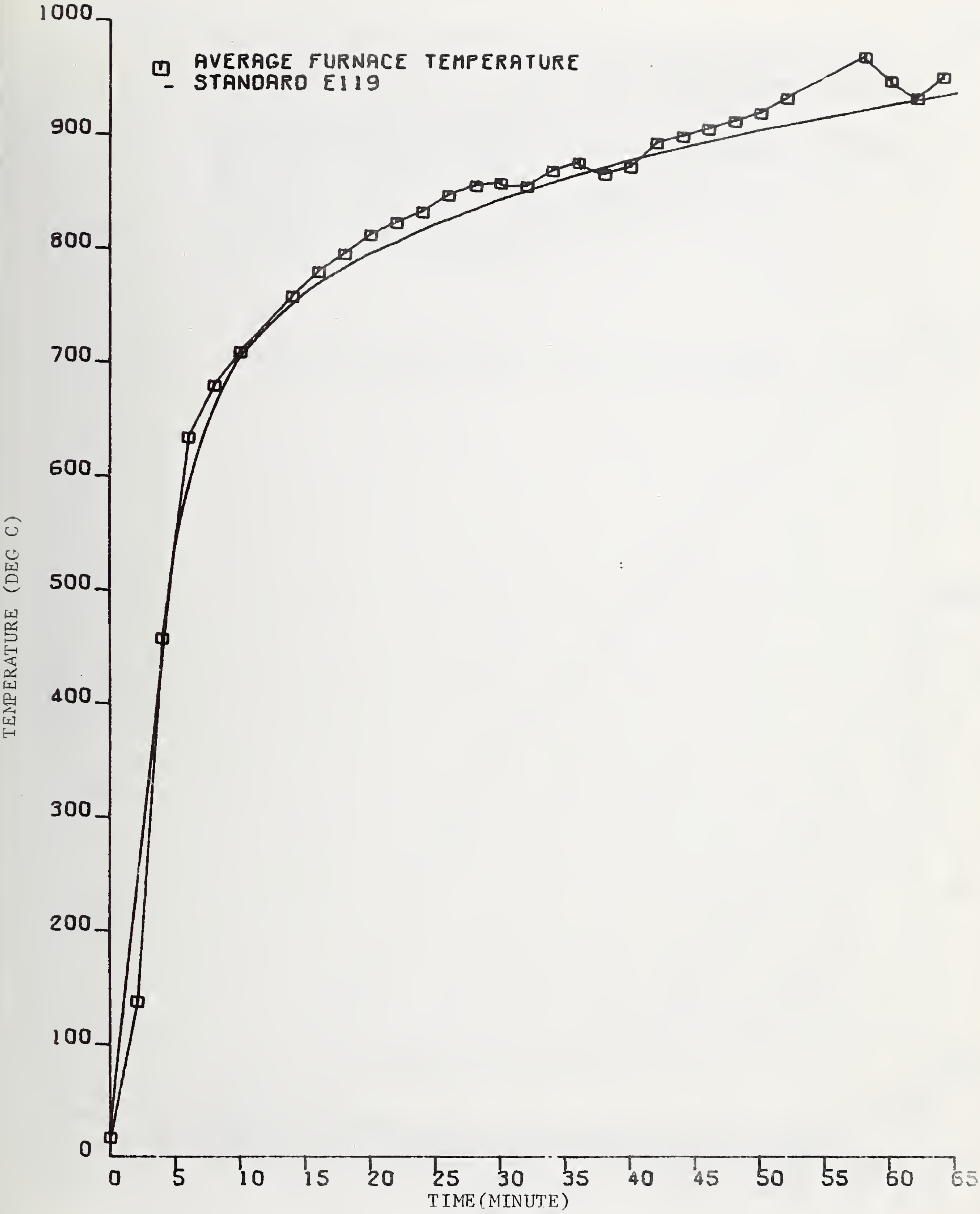


Figure .
AVERAGE FURNACE TEMPERATURE COMPARED WITH STANDARD E119-71 FOR TEST 505.

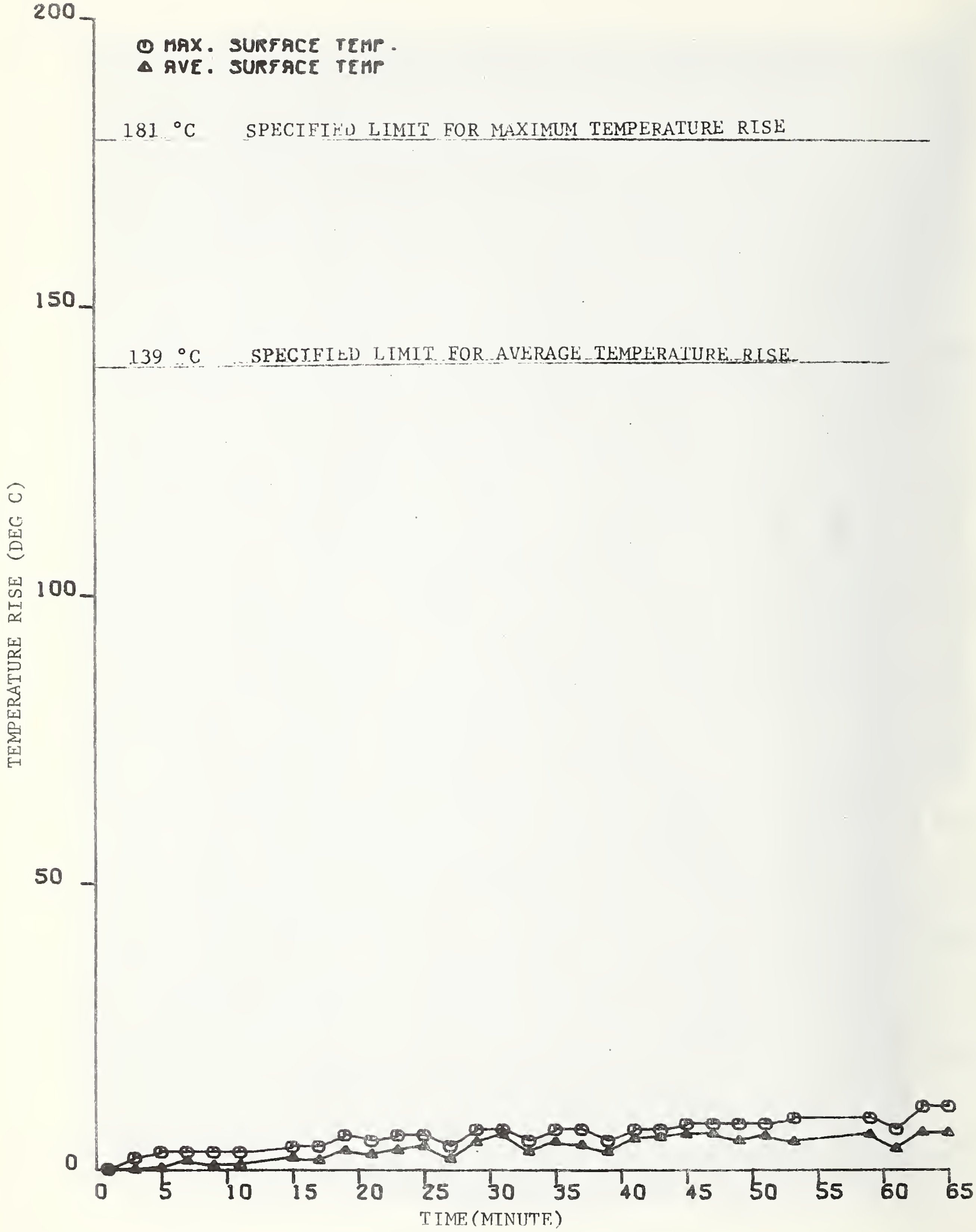


Figure 8.

MAXIMUM AND AVERAGE TEMPERATURE RISE ON THE UNEXPOSED SURFACE TEST 505.

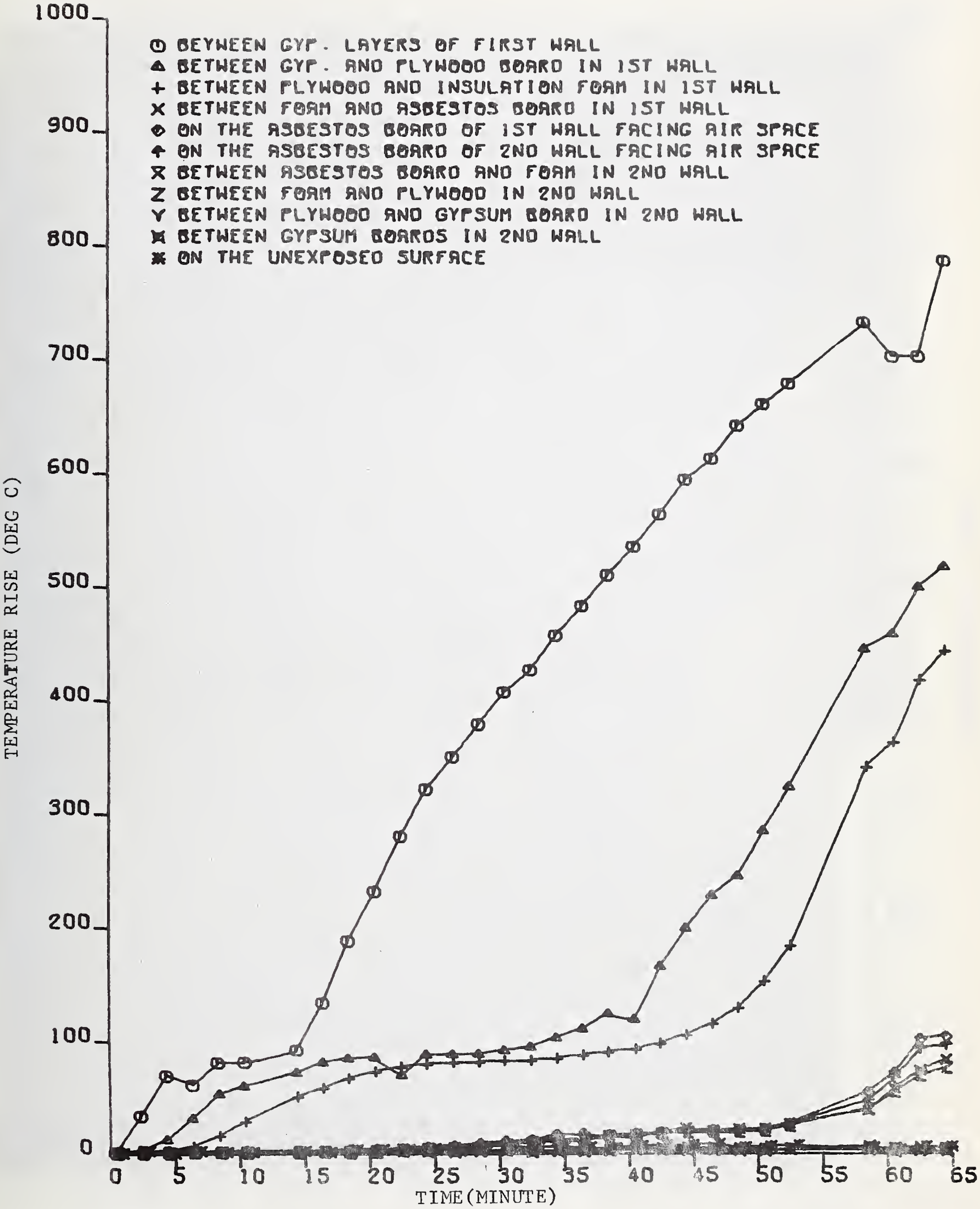


Figure 9.

AVERAGE TEMPERATURE RISE ACROSS THE ASSEMBLY TEST 505.

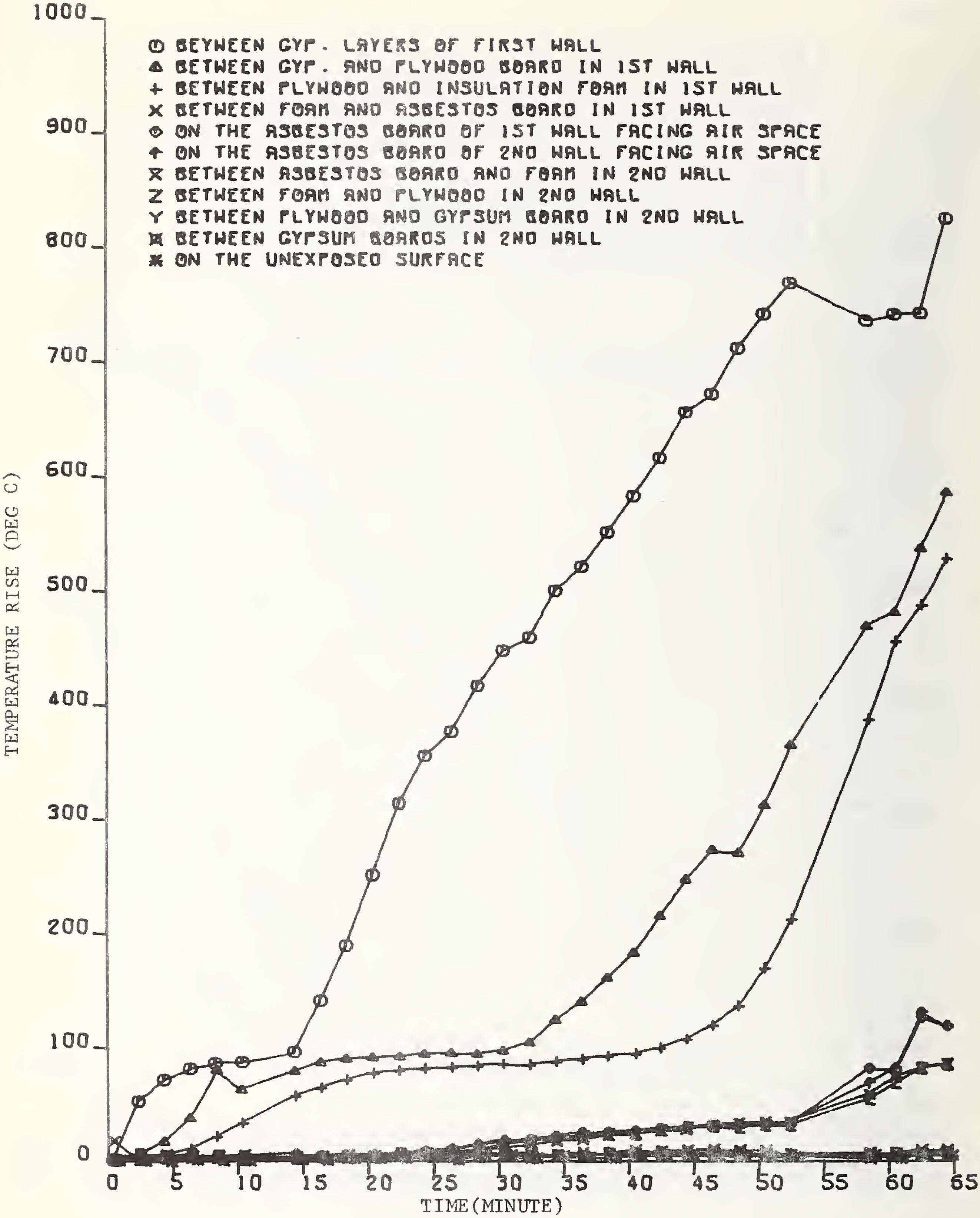


Figure 10.

MAXIMUM TEMPERATURE RISE ACROSS THE ASSEMBLY TEST 505.

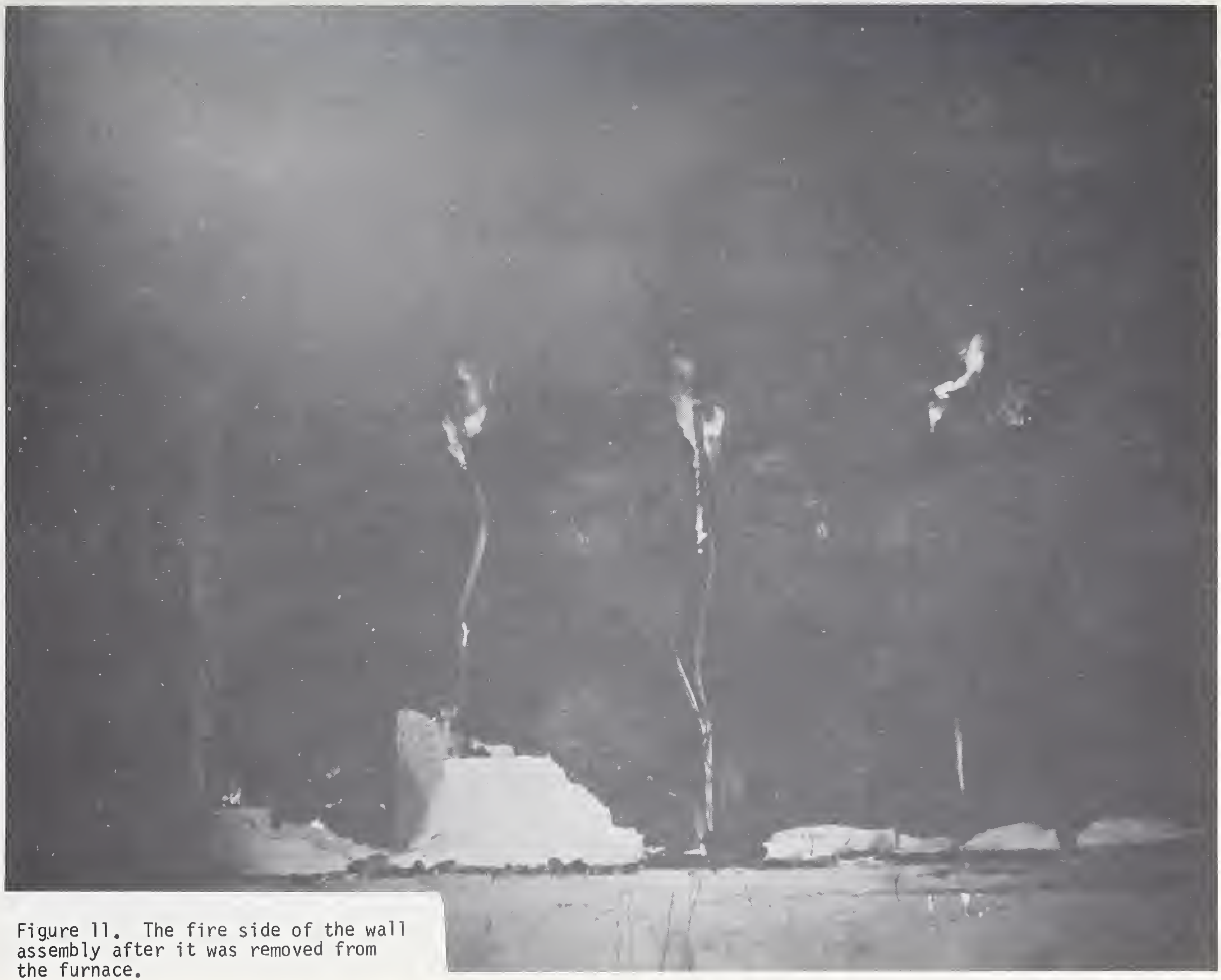


Figure 11. The fire side of the wall assembly after it was removed from the furnace.

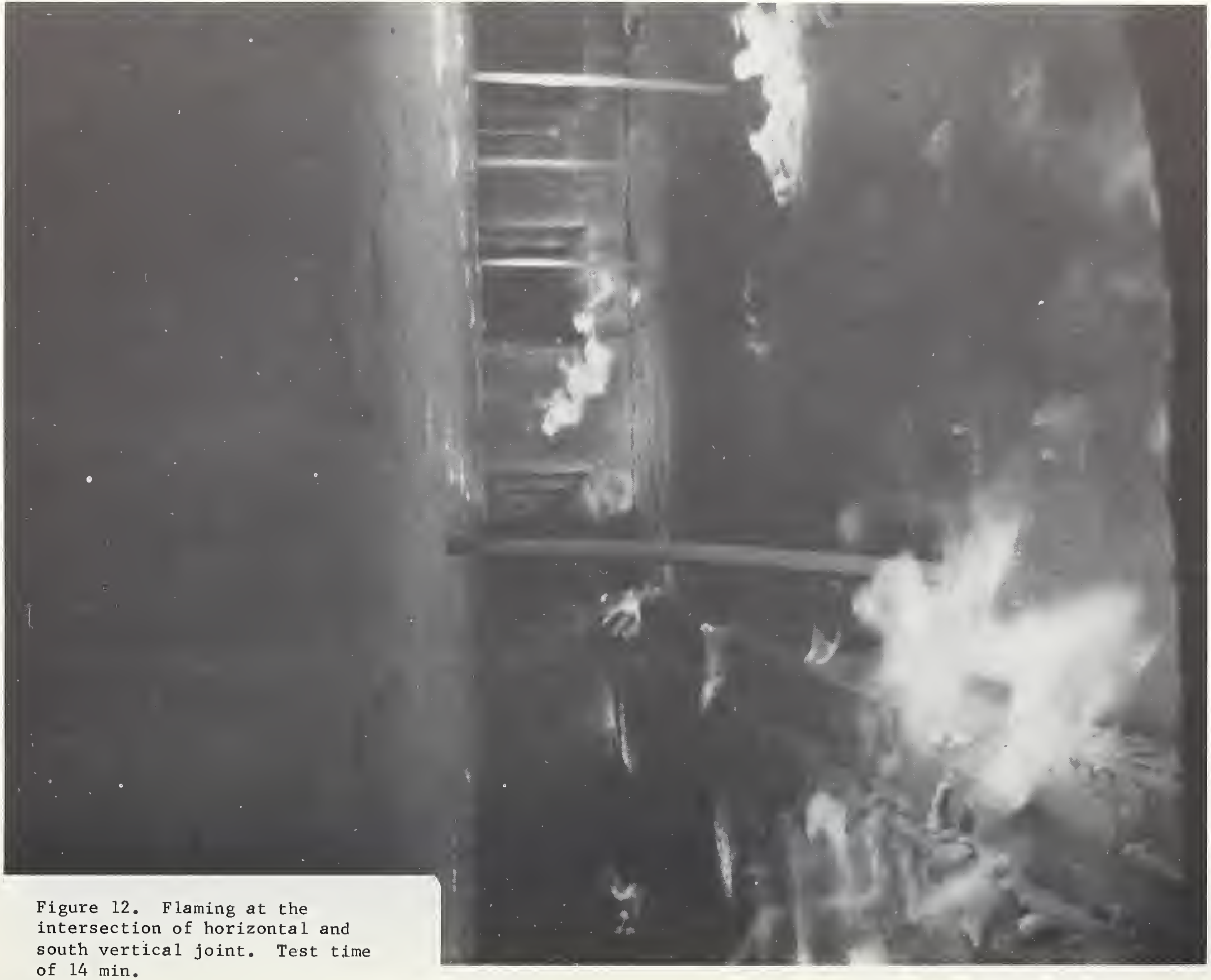


Figure 12. Flaming at the intersection of horizontal and south vertical joint. Test time of 14 min.

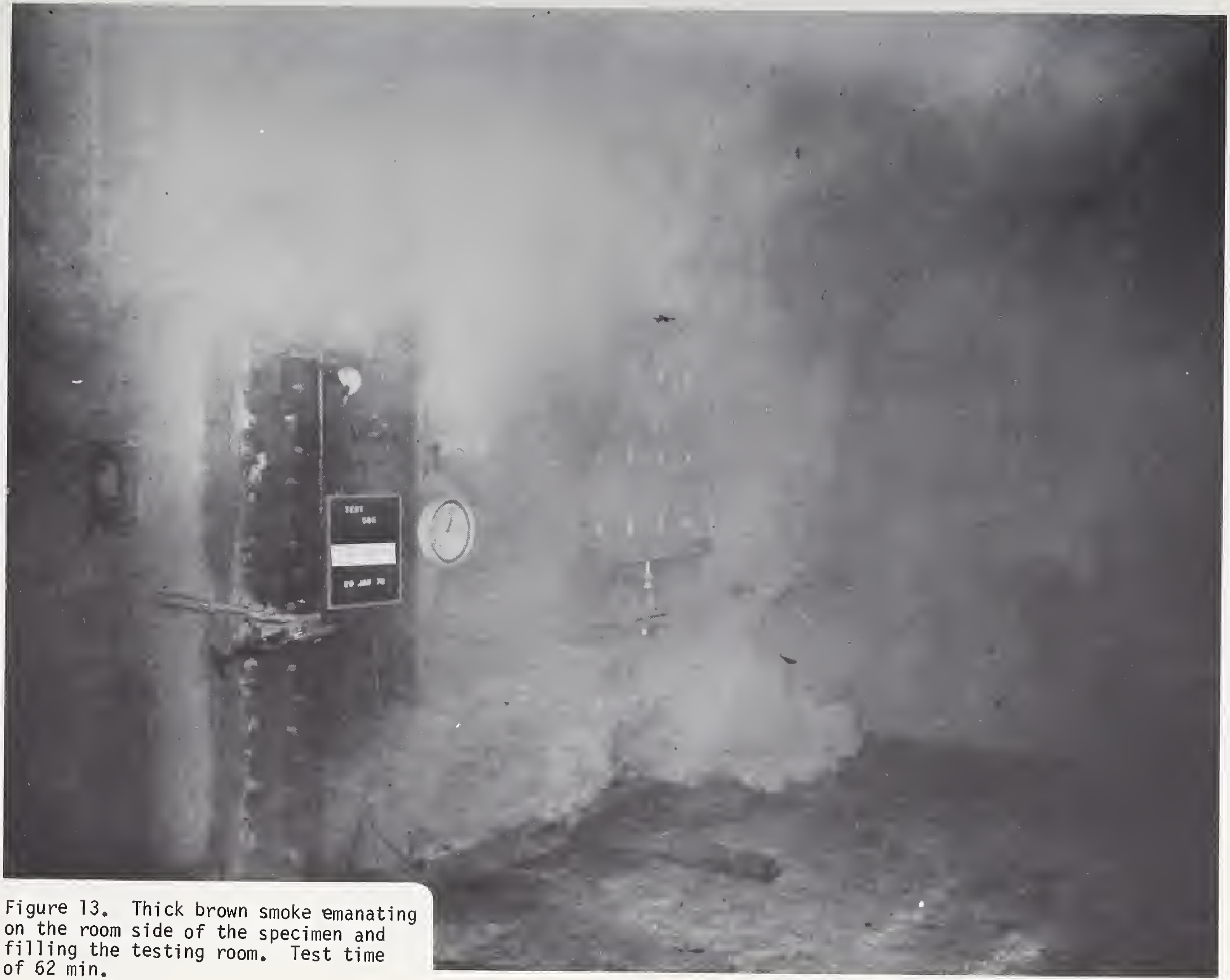


Figure 13. Thick brown smoke emanating on the room side of the specimen and filling the testing room. Test time of 62 min.

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16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

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17. KEY WORDS (Alphabetical order, separated by semicolons) Fire endurance; fire test; housing systems; interdwelling wall; load failure; modular construction; Operation BREAKTHROUGH; polyurethane foam; toxic gases

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